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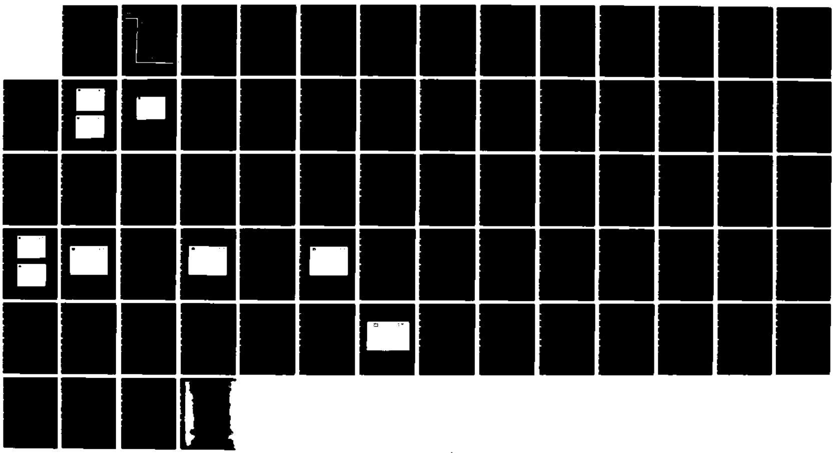

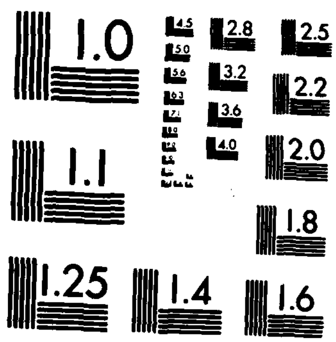

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AIR FORCE HUMAN RESOURCES LABORATORY

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SIMULATED THREE-DIMENSIONAL COMPUTER GRAPHICS TRAINING DISPLAY FOR AIR WEAPONS CONTROLLERS: USERS GUIDE

By

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NOTICE

This paper has been reviewed and is approved for publication.

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A simulated three-dimensional computer graphics display system was developed to address issues critical to the training of Air Force air weapons controllers; primarily those training issues related to air intercept tactics and geometry. The research and development system provided the capability to display and control up to three aircraft in a defined airspace, plus the addition of supplemental graphics to address specific training issues using full-color, raster-scan, animated microcomputer display technology. To transition this technology to the training environment, two video tapes were produced and delivered to the 325th Weapons Controller Training Squadron (formerly the USAF Interceptor Weapons School), where they are being incorporated into the training syllabus. Volume I of this document provides an overview and summary of the project (Final Report). Volume II provides a guide to the operation of the research and development microcomputer system (Users Guide).

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SUMMARY

A prototype of a simulated three-dimensional computer graphics training system was developed to address critical training issues for Air Force air weapons controllers. This system allows the display and control of up to three aircraft flying in a defined airspace and provides special graphics related to the tactics and geometry involved in performing aircraft intercepts.

This Users Guide provides sufficient information for an operator either to control the aircraft interactively via the keyboard (to demonstrate the animated simulation display) or to develop videotapes of scripted mission scenarios (for use as supplemental training aids for air weapons controllers). It also describes the special graphics displays available to the operator.

Although reference is made to software routines, it is not expected that the typical user of this document will be able to write computer code, and this guide is not intended to serve as a programmers guide. No special experience with computers is required to operate this system, although prior experience with either this or other graphics terminals would be useful.

Volume I of this technical paper provides a final report on this effort. It contains additional information on the program objectives and background, plus a discussion of the technical issues involved in the development of this computer graphics system.

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SECTION 1 - SYSTEM DESCRIPTION

PROJECT OVERVIEW

This Users Guide is the second volume of a technical paper that describes an exploratory research and development effort to develop a simulated three-dimensional computer graphics training display system for Air Force air weapons controllers. This effort was specifically aimed at supplementing the training being provided by the USAF Interceptor Weapons School (IWS), Tyndall AFB FL.

Volume I of this document provides a thorough discussion of the background of this effort and the technological issues that were involved. Basically, the need to supplement the training provided by IWS with an additional display simulation capability, which could better demonstrate critical aircraft intercept tactics and geometry issues, was identified as a high priority by HQ Tactical Air Command (TAC). This work was performed on the basis of a TAC Request for Personnel Research (RPR 79-08) titled "Development, Demonstration, and Evaluation of Advanced Training Methods for Weapons Directors and Other AWACS [Airborne Warning and Control Squadron] Mission Team Members."

In response to this request, an effort was initiated to assess the feasibility of developing a three-dimensional computer graphics simulation of aircraft intercepts, with special graphics displays to demonstrate the critical visual training issues. The results of this effort included the in-house experimental computer graphics system and two 3/4-inch cassette videotape recordings of intercept mission scenarios developed for use at IWS. One of the videotapes simulates a stern intercept mission and the other depicts a cutoff intercept mission. Both videotapes are approximately 35 minutes long and have an instructor voice recorded on the sound track. These voice recordings were written and produced by personnel at IWS and simulate a live instructor speaking to students. The instructor describes the visual display and addresses the issues that are relevant to the IWS training program.

This Users Guide is intended for use primarily by personnel who would be giving demonstrations of the system capabilities or by personnel who would be producing additional videotape recordings for use in air weapons controller training programs. It assumes a basic familiarity with computer systems, but not computer programming; and it is expected that the typical user of this guide would probably already have experience with this particular system. It primarily serves the purpose of documenting the capabilities of the system and can be used as a reference document for specific questions on its operation.

This guide is not intended as a software development manual; only general descriptions of the various software routines and capabilities are provided. It should, however, offer all of the basic information necessary to operate the system both interactively ("live flying") and through the use of scripted flight plans, including all of the information needed to develop the flight plans. Two software versions were developed during this effort. The first is a high resolution (1024- by 1024-pixel configuration) version which displays on the Aydin monitor and is used for giving system demonstrations. In this version, control of aircraft flight parameters is accomplished via the keyboard. The second version is a low resolution (240- by 525-pixel configuration) version that displays on the television monitor and is used to develop and record videotapes. Aircraft flight control can be accomplished either interactively through use of the keyboard or by implementing scripted flight plans. The use of both of these versions is further described in Sections 3 and 4 of this paper. The remainder of this section will discuss issues that are common to both versions.

VISUAL DISPLAY

As can be seen from Figure 1, the visual display can be divided into four major areas: the airspace display, the aircraft information display, the zoom/position indicator, and the text line. Each of these will be described separately.

Airspace Display.

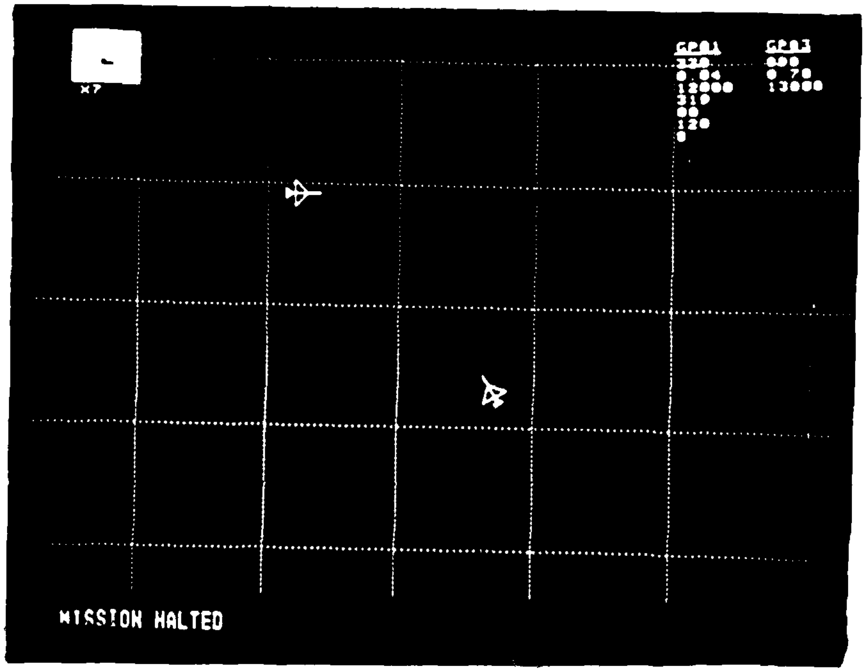
In the center of the display is a grid (viewed from the top down position in Figure 1) which represents the ground over which the aircraft fly. The airspace in which the aircraft can fly is actually somewhat larger than the area covered by the grid. However, the grid provides adequate room in which to maneuver aircraft during intercept missions, and certain limitations will be encountered if they are flown too far outside this airspace (see Section 3, Limitations).

The airspace above the grid is approximately 70 miles on each side and goes from ground level to 28,000 feet in altitude. The aircraft are depicted in this airspace in a simulated three dimensional coordinate mapping system. The visual scene may be viewed from any of three directions: top-down, 45°-angle, and front (side) views. It may also be shifted vertically, horizontally or diagonally, using the directional panning keys, in order to keep the aircraft centered in the viewing screen.

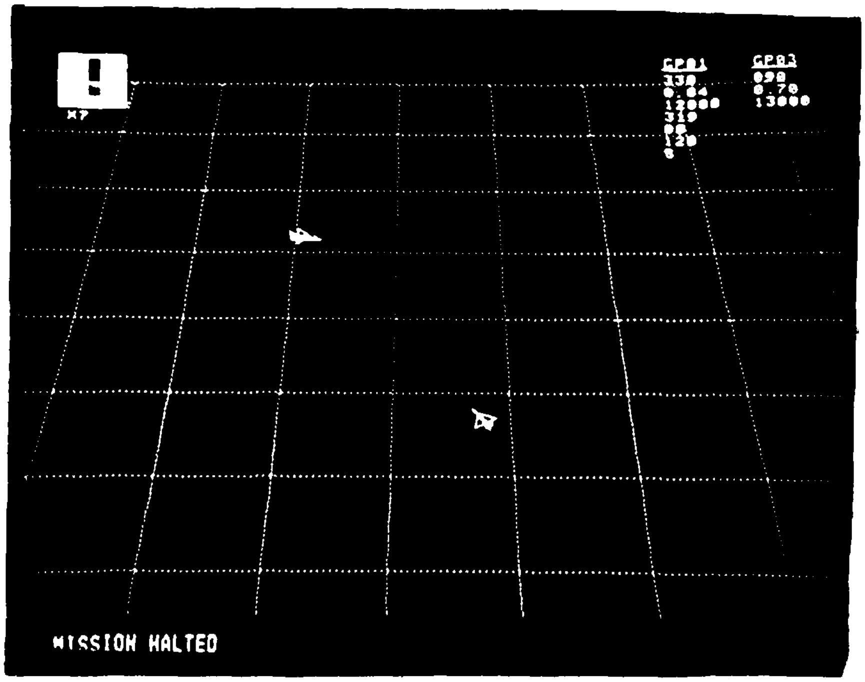
Aircraft Information Display.

In the upper right-hand corner of the display (see Figure 1), information is shown about each aircraft being flown. There are three aircraft which can be displayed: GP01, GP02, and GP03. When only two aircraft are being flown, they will always be GP01 and GP03. When all three aircraft are flown, information about GP02 is added in a third column. All three aircraft are identical and represent a generic high-speed interceptor aircraft. In terms of aircraft shape and performance characteristics, they are most similar to an F-4 or an F-16, although they do not model either of these aircraft exactly. GP03 always plays the role of target.

For each aircraft, information is given about its heading, speed, and altitude. For each interceptor aircraft, the display also

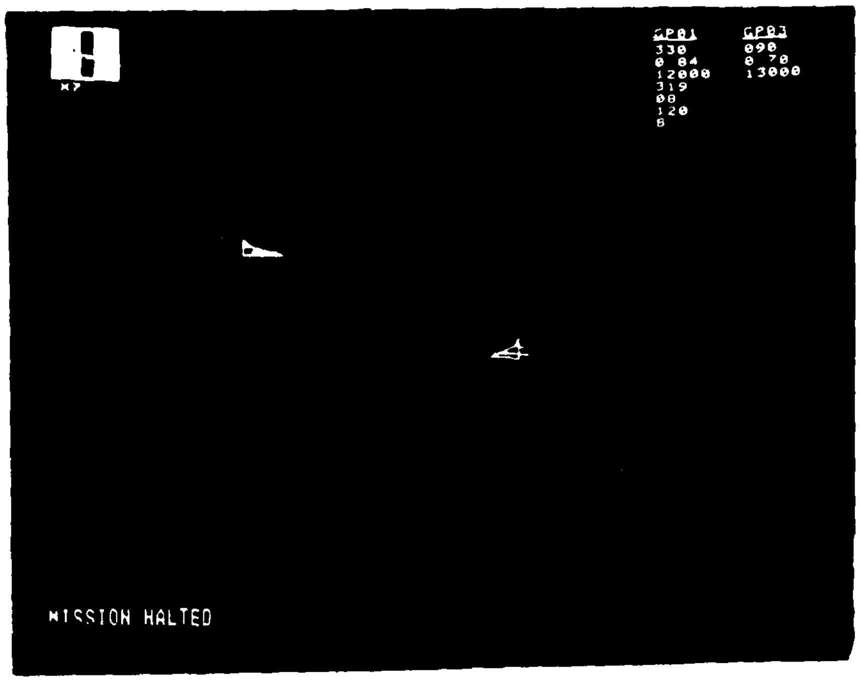


Top-down view



45°-angle view

FIGURE 1. VISUAL DISPLAY.



Front (Side) view

FIGURE 1. (Cont'd)

shows the type of attack to which it is committed, its current target heading crossing angle (HCA), and its bearing and range to the target. When any of this information changes, it is automatically updated on the display. The display was designed to be similar to that provided to students and operational personnel using Semi- Automated Ground Equipment (SAGE)/Back-Up Intercept Control (BUIC) equipment.

Zoom/Position Indicator.

The entire airspace, the amount of zoom being used (i.e., the amount of the total airspace actually being displayed on the CRT), the current position of the aircraft, and the angle of view of the operator are displayed in the upper left-hand corner of the display (see Figure 1).

A zoom value indicator (i.e., X1, X2, X3, etc) is located at the lower left-hand corner of the zoom/position indicator. There are nine zoom values available, with a zoom value of one (X1) showing that all of the airspace is being displayed on the CRT and nine (X9) showing that the smallest available segment of the airspace has been expanded to fill the screen. The portion of the airspace being displayed is colored dark blue, and the background color of the zoom/position indicator is light blue. Thus, it is easy to tell quickly which portion is being displayed and which is not.

The darker portion of the indicator also moves vertically and horizontally corresponding to panning moves made by the operator. Thus, when the position of the viewer is changed, the zoom/position indicator moves to reflect the change.

The shape of the dark blue zoom indicator also corresponds to the portion of the ground surface being shown on the CRT airspace display. Thus, there are different shapes for the top-down, 45° angle, and front views. Although the shape and size of these various possibilities for the zoom/position indicator approximately correspond to

the actual amount and shape of the airspace being viewed, sometimes the aircraft positions on the indicator do not correspond identically with whether the aircraft can be observed on the airspace display.

The position of the aircraft within the zoom/position indicator is represented by short, straight lines similar to the processed radar return seen on manual operational radar equipment. The aircraft are always presented as they would appear from a top-down view.

Text Line.

Along the bottom of the CRT display is a text line that simulates communications between the air weapons controller and the pilots (see Figure 1). Although the aircraft are controlled using language similar to that used in controlling actual aircraft, there are some differences, caused by the fact that the operator is communicating with the computer rather than with an actual pilot. Basically, the differences involve the use of a more restricted language set when interacting with the computer and the computer's requirement that all inputs be made without error. The text line provides error messages when improper inputs are made, such as requesting aircraft to perform maneuvers they are not programmed to perform or when typing errors are made (error messages are described in Section 5).

CAPABILITIES

This research and development system has two basic functions using the three-dimensional graphics display capability. The first allows an operator to use the keyboard to control the flight of all displayed aircraft interactively. This activity can be a useful learning exercise since it provides the operator with a simulated three-dimensional view of the visual scene, whereas standard radar equipment provides only a top-down, two-dimensional visual representation, and because the scene

can be viewed from three different angles. However, interactively controlling the aircraft in real time requires a considerable amount of keyboard typing to input all of the required aircraft commands. Many people find it difficult to perform this task adequately and to observe the visual display at the same time. Thus, the primary laboratory uses for the interactive flying capability are for giving system demonstrations and for flying intercepts as part of developing flight plan scenarios.

The other major system capability is to develop and show scripted mission scenarios (flight plans) to students via videotapes as a supplement to their regular training. There are several advantages to using this capability instead of the interactive flying. First, it is possible to build and show mission scenarios that are designed to demonstrate exactly the types of scenarios that the instructor wants the students to observe. Flight plans can be developed which serve as general purpose reviews of basic intercept tactics and procedures, or which demonstrate advanced concepts and tactics that are difficult to demonstrate using other presentation media. A student would be better able to concentrate on the visual scene being presented using this "flight plan" capability since the requirement for interactive keyboard typing is eliminated.

Another advantage of using the flight plan capability is that it can invoke a software routine that "predicts" approximately 50 frames (30 seconds) ahead for where each aircraft is going to fly. Actually, since the flight plan already contains the aircraft instructions for the whole mission, the computer merely "looks ahead" in the scripted flight plan and then graphically portrays the path that each aircraft will be flying. This feature is particularly useful in training, both because it teaches students to visualize future aircraft movements and because it provides a demonstration of the effects of chosen aircraft headings, altitudes, and speeds on the geometry of the intercept as it will be progressing.

The specialized graphics relating to intercept geometry (to be described later) have more visual impact when they are used with the flight plans because the system user decides, while building the flight plans, exactly when to display these graphics. Thus, it is much easier to present the specialized training graphics at times when they will not be in competition for the student's attention to other events and information display changes occurring in other parts of the visual scene. This allows the student to better concentrate on these special graphics while they are being displayed.

Finally, the most important advantage of the capability of flying aircraft through the use of flight plans is that it allows a system operator or instructor to videotape mission scenarios that depict exactly what the instructor wants to present to students. Sometimes flight plans would be developed which are error-free, from the air weapons controller's point of view. This allows the instructor to present a simulated three-dimensional depiction of an ideal intercept. At other times, errors would purposefully be programmed into the flight plan (e.g., turning an interceptor aircraft too early or too late at an offset point) in order to demonstrate how and when course corrections should be made. Up to 30 separate flight plans can be developed, stored, and displayed from the TV/videotape disk. The details of how to build flight plans are described in Section 4.

HARDWARE AND FIRMWARE

The hardware used was an Aydin 5216 Graphics Display System consisting of:

- Aydin 5216 Graphics computer (with nine display memory bit planes)
- Aydin 8026 High resolution monitor
- Aydin 5116 Keyboard

Additional equipment included:

Perkin-Elmer VF-1221 Cartridge Disk Drive (with controller)
Lenco PCE-462 Color Encoder
Lenco CSL-710D Sync Generator
Sony Cassette Recorder
Sharp TV/Monitor

The interface between the hardware and the applications software was a programmable read only memory (PROM) firmware set called AYGRAF/3D. This firmware contains the basic simulated three-dimensional graphics routines. It should be noted that these routines are transparent to the system operator and cannot be modified without actually producing new firmware (PROM).

SOFTWARE

The software was written using FORTH, a high-level graphics programming language. FORTH is a hierarchically structured language that allows the programmer to develop successively more complex routines by building on previously defined variables and procedures to develop a dictionary that requires minimal memory storage space and executes quickly.

It is important to remember that the FORTH dictionary stores words by listing a number representing the total number of letters in the word and the first three letters of each word. For example, the word TURN would be stored as 4TUR and the word CLIMB would be stored as 5CLI. This method should not cause any problems for the operator, but it does allow the computer to accept words that are misspelled, as long as the first three letters and the total length are correct. For commands that are more than one word in length (such as "SET SPEED 0.85"), the computer

will usually be looking for one key word, in this case "SPEED"; "SET" is defined as a null word (i.e., if typed alone, it would be accepted but would have no effect).

The software for this system consists of two major software components: AYGRAF/3D and the user-developed procedures.

AYGRAF/3D is a comprehensive graphics turn-key software package developed by Aydin, Inc. for use on the Aydin 5216. It consists of an interactive FORTH compiler, extensive three-dimensional graphics instruction set and an integrated operating system. AYGRAF/3D supports a direct binary data transfer and stand-alone keyboard input on the Aydin 5216. As stated, AYGRAF/3D is self-contained in a PROM firmware set. For this effort, AYGRAF/3D was used in a stand-alone configuration, with input from the keyboard (interactive) or disk (scripted flight plans).

The user procedures, as designed, describe an airspace model (three-dimensional cube), an aircraft model, and selected text display windows for keyboard input echo or messages and for flight status parameters. The various models were drawn on different memory planes to permit the use of different colors and color priority. The user procedures were implemented as two tasks: TWO-FLY (draw and display current picture) and operator or flight plan input processors. The procedures package is initialized with user-defined defaults; e.g., current aircraft positions, speeds, and headings. TWO-FLY continuously computes and displays the next aircraft position based on the current aircraft parameter values.

The input processor tasks allow the operator or the flight plan to modify the current aircraft parameters to effect speed changes, climb or dive, and turn. The display may also be changed via input processors to draw one or two interceptors plus a target aircraft; to pan the airspace; to zoom; to stop/start the display; to overlay the bearing vector, intercept vectors and cone of attack graphics; and to display the flight predictor (look-ahead) graphic.

In order to avoid the undesired visual effects of image clearing and redrawing, TWO-FLY utilizes two sets of image memory planes: one for the current display and the other for the next display. A routine called PING-PONG alternates the memory planes referenced by the software on each redraw/display cycle and addresses to the appropriate video color look-up table. The blinking of a successful target kill and selected graphics planes to effect an on/off visual display is also performed on PING PONG cycles.

The software incorporates all the logic necessary to validate an operator request and to have the aircraft models respond in a visually realistic manner. A significant amount of time was spent in fine tuning the incremental adjustments in climbs, dives, and turns, and the determination of a command's validity based on the current aircraft's maneuver. Examples of validation errors, in addition to value out-of-range, are commanding "Level off" when not diving or climbing and "Roll out" when not in a turn. Other examples are listed in Section 5.

In addition to realistic aircraft movements, enhancements were added to linearize the zoom capability for a more pleasing size progression, to support TOP, FRONT, and 45° view angles, and for auto-centering of the aircraft on the display screen.

Additional effort during software development included work on display layout, character sizes, color selection, go/no-go conditions for operator commands with appropriate rejection messages, three dimensional vector computations, and incremental vector change computations. Also involved were the assignment and layout of single command function keys to reduce typing requirements; the addition of vector and cone display restrictions based on aircraft range; and the addition of aircraft annotation display restrictions based on time, movement with aircraft, and the relative positions of the aircraft.

SECTION 2 - INITIALIZATION AND SET-UP

The routine for starting up the computer and other equipment and for displaying the animated picture on the screen is fairly straightforward. The power switches on each piece of equipment are connected to standard 110-volt power lines. After all the equipment has been turned on, the operator decides whether the high resolution CRT version or the TV/videotape version is going to be used and mounts the appropriate disk into the disk drive. Each version is kept on its own well-marked disk, and backup disks are kept for both programs. If any problems are encountered up to the point where the appropriate disk has been mounted and the disk drive enabled, the laboratory facility manager should be contacted to correct any possible problems.

To properly set up the software, the computer system first has to be initialized. This is done by pressing the "Initialize" button located on the back of the keyboard. If there are no problems up to this point, the words "AYDIN 3-D" will appear on the top text line of the CRT screen.

At this point, all of the equipment will be functioning properly and the next step will be to load the software. Typing the command 3 LOAD, followed by a carriage return [CR] on the keyboard, loads the FORTH nucleus into the computer main memory. If this command is accepted and executed, the prompt "OK" will now appear on the screen. If it does not, the system should be reinitialized.

To load the main flying program, 398 LOAD is entered via the keyboard. Approximately 3 minutes later, the visual scene will appear on the screen and the aircraft will be flying under keyboard control. There are preset aircraft starting positions and flight parameters to allow the scenario to always begin at the same place. At this point, to switch to the scripted mission scenarios written into the flight plans, the number of the desired flight plan (e.g., 3 PLAN) is entered via the keyboard.

The aircraft will assume the initial positions and flight parameters designated in the flight plan and will fly the mission called for. Section 6 provides a Quick Reference Guide that can be easily referred to during system initialization and set-up for a listing of the critical steps and keyboard commands.

SECTION 3 INTERACTIVE USE

OVERVIEW

As described earlier, this system can be used to control the aircraft interactively from the keyboard. This is accomplished, after system initialization and set-up as described in Section 2, through the use of typed-in commands and function keys using the keyboard. This section will describe how to control the aircraft interactively by using the keyboard commands and viewing controls and how to use the special training graphics relating to intercept geometry.

KEYBOARD COMMANDS AND VIEWING CONTROLS

There are four major areas on the standard Aydin Controls, Inc. keyboard: (a) the alphanumeric keys, (b) a two-row set of user-defined function keys, (c) a numeric key pad, used with the zoom capability, and (d) the cursor keys, used with the panning and directional viewing change capability. Each of these will be described separately.

Keyboard.

The alphanumeric keys are similar to those of many other standard keyboards and need no special instructions for proper use. Both words and numbers can be input to the computer. The only item to remember is that the Carriage Return [CR] key must be depressed after each command is typed in order to send the command to the computer. When the aircraft are being flown, the alphanumeric symbols which are typed appear on the text line at the bottom of the display. This text line is 80 characters in length. When commands are input, the computer searches through the FORTH dictionary to find the definition of the command, and the command is executed.

When flying interactively, it is important to observe the monitor text line after a command is input to make sure that it has been accepted. If the command has been accepted, the text line will automatically clear itself. If a command has been misspelled or an illegal command has been input, the words "INVALID COMMAND" will appear on the text line. If a legal command has been input, but some parameter has been exceeded, such as attempting to make an aircraft fly slower or faster than it is capable of flying, the error-checking capability of the system will recognize the error and provide feedback in terms of an error message that appears on the text line. The complete set of error messages is described in Section 6.

Function Keys.

The keyboard contains two rows of user-defined function keys. These keys have been assigned functions in an arrangement which seems to maximize the ease with which they can be used during interactive flying.

As can be seen from Figure 2, there are three general groupings for the function keys. Those on the left side pertain to the display and program start/stop options; the central portion provides the aircraft designator and special training graphics display functions; the right side relates to the viewing controls. Table 1 provides a description of the separate functions.

Numeric Key Pad.

On the lower right portion of the keyboard is a standard numeric key pad with numbers from 0 through 9 (the two blank keys are not used). These numbers are primarily used with the display zooming function, although they can also be used to input any numerical information instead of using the numbers on the alphanumeric keyboard. To use the numeric key pad with the zoom function, the [SHIFT] key is depressed, and a number is depressed concurrently. The appropriate zoom is automatically

(NOT USED) X	STOP	2 INT DISPLAY
END	GO	1 INT DISPLAY

LEFT SIDE FUNCTION KEYS

CUTOFF ATTACK	NO ATTACK	(NOT USED) X	NO CONE	INTERCEPT VECTORS	CONTRAIL DISPLAY	CONTRAIL RESET	BEARING	TURN TO BEARING
STERN ATTACK	PURSUIT ATTACK	LEFT CONE	RIGHT CONE	GP2	TGT	GP1	BEARING VECTOR	BEARING & RANGE

CENTER FUNCTION KEYS

45° VIEW	TGT-GP1 CENTER
FRONT VIEW	TOP VIEW

RIGHT SIDE
FUNCTION KEYS

FIGURE 2. KEYBOARD FUNCTION KEY ARRANGEMENT

Table 1. Description of Keyboard Function Keys

Function Key	Function Description
END	Terminates all flying and display routines. System must be reinitialized before flying may be resumed.
STOP	Flying routines are temporarily stopped and "MISSION HALTED" is displayed on the CRT display text line. Keyboard is still active but no flying command actions are taken on inputs until flying is resumed. Special graphics and zoom/position controls are still available.
GO	Resumes all flying and display routines.
2 INT DISPLAY	Displays aircraft and associated data for GP01, GP02, and GP03.
1 INT DISPLAY	Displays aircraft and associated data for GP01 and GP03.

Table 1. (Cont'd.) Description of Keyboard Function Keys

Function Key	Function Description
CUTOFF ATTACK	Commits identified aircraft (GP01 or GP02) to cutoff attack. "C" appears on aircraft data display.
STERN ATTACK	Commits identified aircraft (GP01 or GP02) to stern attack. "S" appears on aircraft data display.
NO ATTACK	Cancels declared attack type for identified aircraft.
PURSUIT ATTACK	Commits identified aircraft (GP01 or GP02) to pursuit attack. "P" appears on aircraft data display.
LEFT CONE	Displays appropriate cone of attack for identified interceptor and attack type from left side of target. If no attack type has been declared for interceptor, defaults to cutoff cone of attack.

Table 1. (Cont'd.) Description of Keyboard Function Keys

Function Key	Function Description
NO CONE	Erases any cone currently being displayed.
RIGHT CONE	Displays appropriate cone of attack for identified interceptor and attack type from right side of target. If no attack type has been declared for interceptor, defaults to cutoff cone of attack.
INTERCEPT VECTORS	Displays 3-line intercept vectors display (See Figure 4).
GP2	Identifies GP02 as aircraft about to receive flying command. If interceptor is 10 miles or more away from target, displays aircraft identifier.
GP1	Same as GP2, for GP01.
TGT	Same as GP2, for GP03 (target).

Table 1. (Cont'd.) Description of Keyboard Function Keys

Function Key	Function Description
CONTRAIL DISPLAY	Displays aircraft flight path display (see Figure 6).
CONTRAIL RESET	Resets aircraft flight path display to zero frames of data memory and display.
BEARING	Displays bearing vector graphic (see Figure 5) for three frames.
BEARING VECTOR	Displays bearing vector graphic (see Figure 5) until it is turned off by second key depression.
BEARING & RANGE	Displays bearing vector graphic (see Figure 5) and alphanumeric display of current bearing and range to target for identified interceptor on text line at bottom of airspace display.

Table 1. (Concluded) Description of Keyboard Function Keys

Function Key	Function Description
TURN TO BEARING	Initiates turn for identified interceptor to same heading as current bearing to target. Used in implementing pursuit attack.
45° VIEW	Rotates visual scene so that it is viewed with a 45° look-down angle from a point midway along the top of the front of the airspace.
FRONT VIEW	Rotates visual scene so that it is viewed from a point midway down the front side of the airspace, with a 0° look-down angle.
TOP VIEW	Rotates visual scene so that it is viewed with a 90° look-down angle from a point midway along the center line of the top of the airspace.
TGT - GPI CENTER	Automatically centers, in 6 frames, target (GP03) and GP01 in display field, so that both aircraft are equidistant from center of screen.

displayed when a number is depressed. When the zoom display is changed, the zoom/position indicator display is automatically modified. The only limitation on the use of this function is that it cannot be changed concurrently with a change in viewing position.

Panning Cursor Keys.

On the upper right portion of the keyboard are the directional cursor keys which are used to make incremental changes in the viewing position. This viewing change capability implements a two-dimensional panning (left-right, up-down, or diagonal) that is used to keep aircraft in the central viewing portion of the monitor. This incremental panning capability is separate from the viewing position function keys (top, front, or 45° views). It can be used regardless of which major viewing position is currently being shown.

There are 16 incremental steps available in each direction, and diagonal moves are possible by depressing any two adjacent direction keys (e.g., depressing $\lfloor\rightarrow\rfloor$ and $\lfloor\downarrow\rfloor$ produces a $\lfloor\searrow\rfloor$ move). The only limitations on the use of this capability are (a) directional moves will stop when X, Y, Z limits are reached at the edges of the airspace, and (b) this capability cannot be activated concurrently with other viewing position or zoom function changes. The directional panning capability can either be invoked one discrete step at a time or the key(s) can be held down for several moves in succession. In addition to the directional panning keys, the HOME key in the center of the directional arrow keys can be used to bring the viewer back to the center of the visual display. This function performs the centering move in six steps, regardless of whether the scene is being viewed from the top, 45°-view, or front visual angle; it merely centers the viewer with the same visual angle.

FLYING COMMAND LANGUAGE

The flying command language is quite similar to that actually used by air weapons controllers. Table 2 provides a list of the flying commands available.

Using this flying language is quite simple. The commands, with a space between each word, are typed on the keyboard and input to the computer by depressing the "CR" key. Commands may be linked together, such as "GP1 TURN RIGHT 125 SET SPEED 0.75"; however, it is usually better to input commands individually, such as "GP1 TURN RIGHT 170." The reason for this is that it is more difficult to identify errors and retype a string of commands when a typing mistake is made than it is to retype a single command.

SPECIAL TRAINING GRAPHICS

In addition to the graphics display of the aircraft and airspace, special graphics routines were developed to address the critical training issues identified by the staff of the USAF Interceptor Weapons School. Figures 3 through 7 present illustrations of these graphics.

Intercept Cone of Attack.

As Figure 3 shows, the proper cone of attack for each attack type can be displayed. Each display has lines which comprise the cone within which the interceptor must be positioned to achieve an acceptable intercept. The cones can be displayed either with the flying program stopped (STOP - "MISSION HALTED") or while they are still flying. In the latter case, the cone will move along with the target on each frame. The length of the cone lines will be roughly 1-1/2 times the distance between the identified interceptor and the target, except that they will not display when the aircraft are within 3 miles of each other. The only

Table 2. Flying Command Language
High Resolution CRT Version

Command	Notes/Limitations
RIGHT nnn	Turns designated aircraft to the right to indicated heading using 30° angle of bank. Aircraft turns 5° of heading change each frame. New heading must be in the range 1° to 360°.
LEFT nnn	Turns designated aircraft to the left to indicated heading using 30° angle of bank. Aircraft turns 5° of heading change each frame. New heading must be in the range 1° to 360°.
TIGHT TURN	If aircraft identified is in a standard turn, causes it to implement 45° angle of bank turn. Aircraft turns 15° of heading change each frame.
CONTINUE nnn	Causes identified aircraft to continue to fly current heading. "nnn" must be the same as current heading.

Table 2. (Cont'd.) Flying Command Language
High Resolution CRT Version

Command	Notes/Limitations
$\boxed{\text{TGT}}$ or $\boxed{\text{TARGET}}$	Identifies GP03 as aircraft about to receive a flying command. If last command was given to the same aircraft, it does not need to be reidentified. If GP01 and GP02 are greater than 10 miles away, also causes aircraft identifier to be displayed.
$\boxed{\text{GP1}}$	Same as above for GP01. This aircraft may be called either GP01 or GP1, but display is GP01.
$\boxed{\text{GP2}}$	Same as above for GP02.
$\boxed{\text{CLIMB nnnnn FEET}}$	Causes identified aircraft to climb to indicated altitude, which must be less than 50,000 feet. FEET is a null word.

Table 2. (Cont'd.) Flying Command Language
High Resolution CRT Version

Command	Notes/Limitations
DIVE nnnnn FEET	Causes identified aircraft to dive to indicated altitude, which must be greater than 2,000 feet. FEET is a null word.
LEVEL OFF nnnnn FEET	Causes identified aircraft to stop current climb or dive and level-off at identified altitude. Must be input at least six frames before aircraft reaches desired altitude, to give aircraft time to step out of current climb or dive. LEVEL and OFF are null words.
SET SPEED n.nn	Causes identified aircraft to change speed, in Mach, to identified speed, which must be in the range .50 Mach to 2.00 Mach. SET is a null word.
1 INT	(1 Interceptor) Displays GP01, GP03 and their associated data on CRT.

Table 2. (Cont'd.) Flying Command Language

High Resolution CRT Version

Command	Notes/Limitations
$\boxed{\text{2 INT}}$	(2 Interceptors) Displays GP01, GP02 and GP03 and their associated data on CRT.
$\boxed{\text{STOP}}$	Causes aircraft flight to stop and displays "MISSION HALTED" on text line. Interactive commands may still be input, but are not acted on until $\boxed{\text{GO}}$ is input. Special graphics may be displayed during $\boxed{\text{STOP}}$.
$\boxed{\text{GO}}$	Causes aircraft to reinitiate flying.
$\boxed{\text{END}}$	Totally stops all flying routines. System must be reinitialized to begin flying again.

Table 2. (Concluded) Flying Command Language
High Resolution CRT Version

Command	Notes/Limitations
JUDY	Input to computer when the operator has finished positioning aircraft for final stage of intercept and would expect real pilot to take over intercept control. Command queries system concerning whether flight parameters (heading crossing angle, speed ratio, altitude separation, distance from target) are within bounds for type of attack declared for intercept to be successful. Successful intercept gives flashing graphic display. Unsuccessful intercept gives error messages listed in Section 5.

limitation on the use of the cone display is that the aircraft should be no further than 35 miles apart when the cone is displayed.

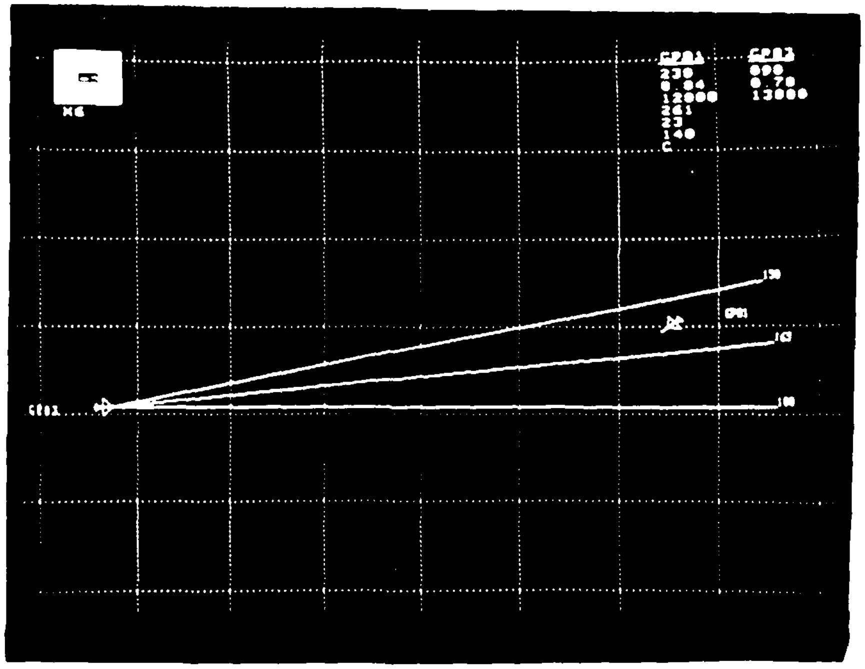
During interactive flying the cone is displayed by selecting either the |LEFT CONE| or |RIGHT CONE| function keys. Thus, it is important to quickly visualize whether the interceptor is approaching the target from the left side or the right side. Before displaying the cone, an interceptor must be committed to a type of attack (stern, etc.) before the cone for that particular type of attack can be displayed. If a left cone or right cone is chosen to be displayed before an attack commitment is made, the system defaults to a display of the cutoff cone. The cone display is quite useful for quickly determining whether an interceptor is "hot" or "cold" (i.e., early or late) on a particular type of attack and estimating how much correction, if any, is needed.

The cone for the cutoff attack has lines radiating from the target in the direction from which the interceptor is approaching on the 180^{o}, 165^{o}, and 150^{o} Heading Crossing Angle (HCA) lines. There is no Turn Point display for the cutoff attack.

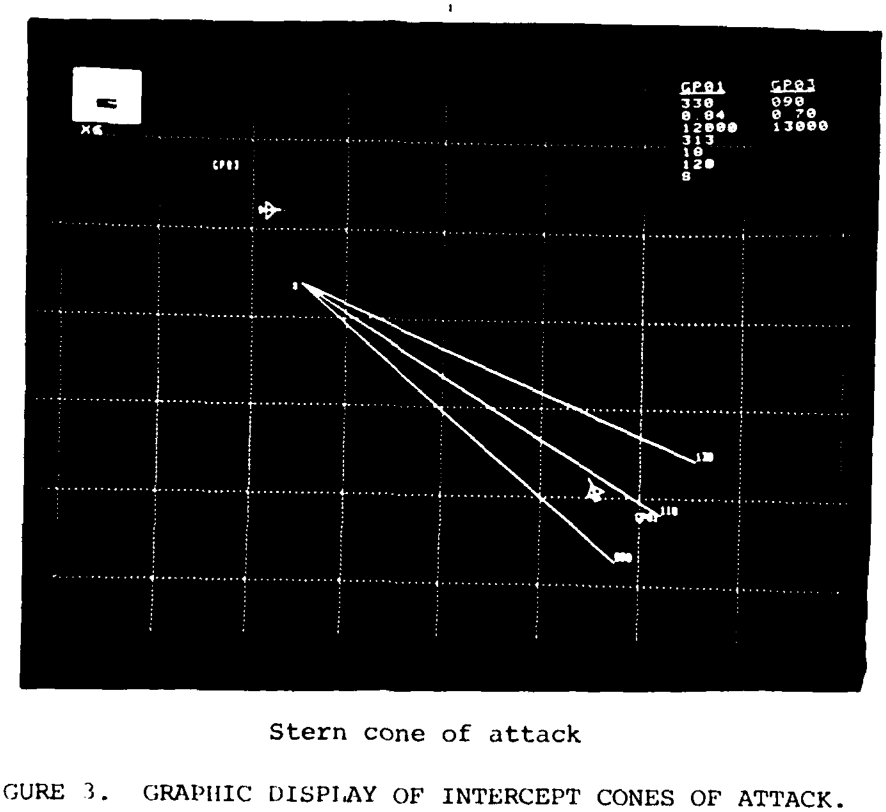
The only difference between the Pursuit cone (not shown in Figure 3) and Stern cone is that the Pursuit cone radiates from the front of the target aircraft and the Stern cone radiates from a Turn Point. The Turn Point is approximately 3-1/2 miles directly to the side of the target. The position of the Turn Point corresponds roughly to the correct placement for a 110^{o} HCA Stern attack and will be somewhat inaccurate for Stern attacks of different HCAs. Thus, it is only a close approximation of the correct Turn Point position and is useful as a training graphic primarily during the initial phases of the intercept.

Intercept Vectors.

As Figure 5 illustrates, it is possible to display the intercept vectors, one of the critical intercept geometry displays. The intercept vector display is a triangle which is composed of the target heading



Cutoff cone of attack



Stern cone of attack

FIGURE 3. GRAPHIC DISPLAY OF INTERCEPT CONES OF ATTACK.

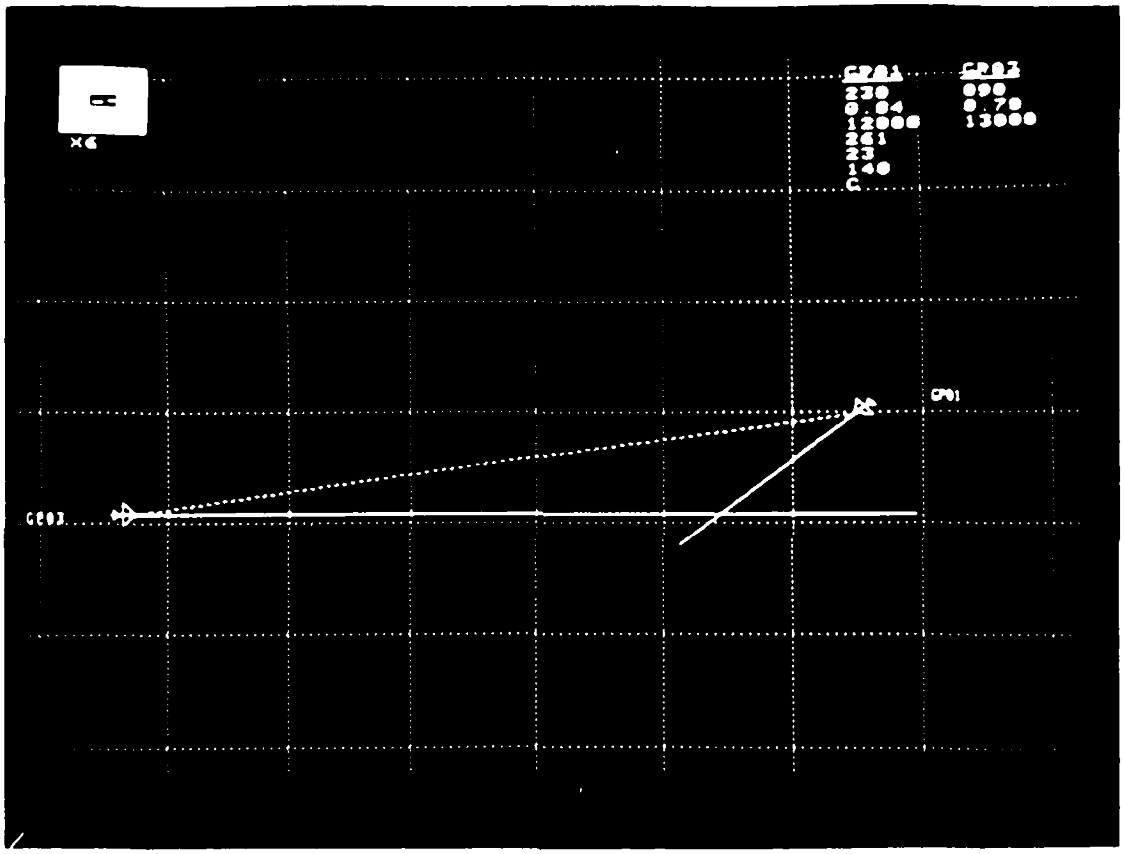


FIGURE 4. GRAPHIC DISPLAY OF INTERCEPT VECTORS.

line, the interceptor heading line, and a line representing the bearing from the interceptor to the target.

This display can be initiated either with the aircraft flying or stopped, although it should be displayed only when the aircraft are within 35 miles of each other. It is not necessary to have the interceptor committed to an attack type before displaying the intercept vectors.

The length of the target and interceptor heading lines are not a predetermined, fixed length. Generally, they extend 20 miles when they do not intersect, but are reduced to show only a small amount of overlap when they do intersect. This reduction in length when the lines intersect allows students to focus their attention better on the triangle formed by the three lines.

In using this display, students can tell whether an interceptor heading correction is needed and, if so, in which direction. Also, the difference between the direction of the interceptor heading line and the bearing-to-target line graphically demonstrates the "angle off," which is provided to pilots in quantitative terms. It is hoped that this graphic portrayal will help students better understand this numerical concept.

Bearing Vector.

The bearing vector display, as shown in Figure 5, is a graphic depiction of the bearing from an identified aircraft to the target. It is identical to the bearing vector used as part of the intercept vectors display. The primary usefulness of the bearing vector display is that it focuses a student's attention on the direction of this vector and, again, provides a visual representation of information given to pilots as a number. In addition, it demonstrates the independence of the bearing from the actual headings of the aircraft.

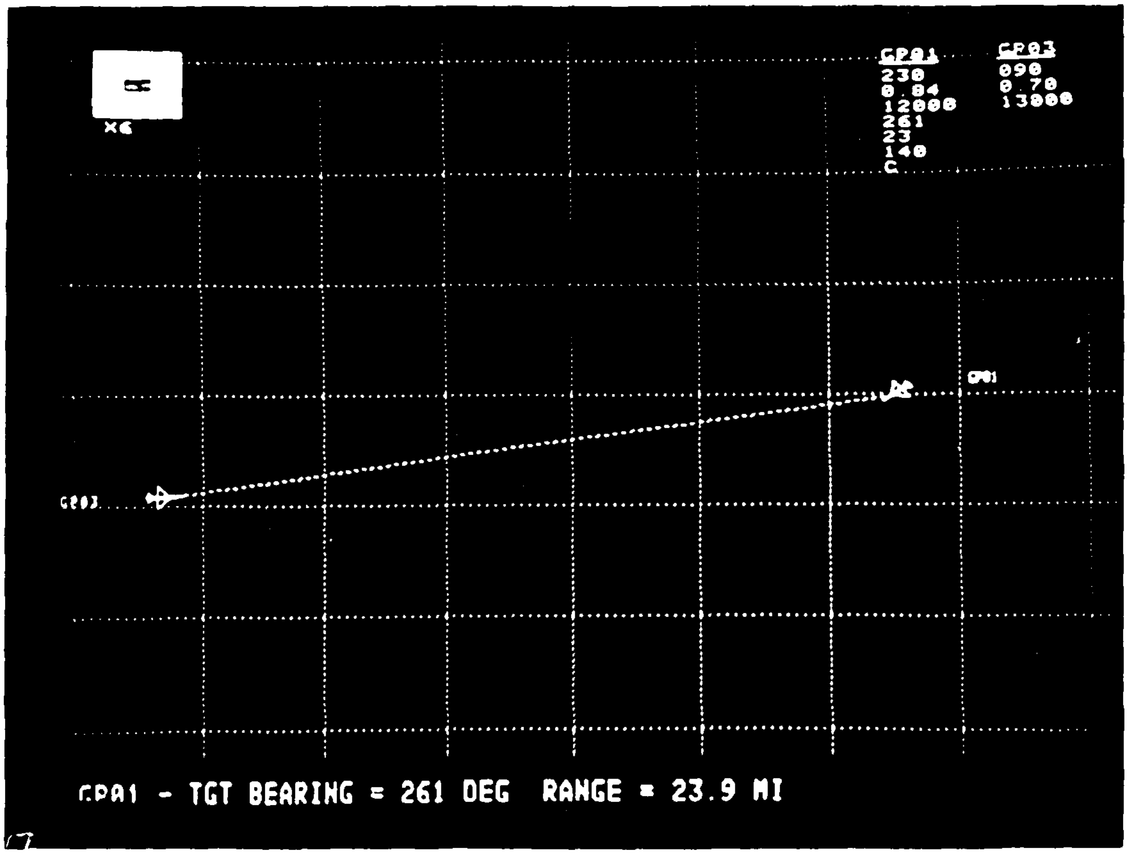


FIGURE 5. GRAPHIC DISPLAY OF BEARING VECTOR.

Flight Path Display.

One of the more interesting graphic displays is the flight path display, demonstrated in Figure 6. This display is similar to the data trail displayed in SAGE- and BUIC-type automated aircraft control systems. The primary difference is that the flight path display in this system is considerably longer, allowing the student to observe more of the flight path followed by the aircraft during an intercept, and thus better understand the geometry and progress of the intercept. It is especially useful after major aircraft turns are made, allowing the student to "look back" and see what the aircraft have done.

CAPABILITIES AND LIMITATIONS

This system allows the operator to control all of the major flight parameters of the simulated aircraft. GP01 or GP02 may be controlled as fighter aircraft flying intercepts, with GP03 as target. Virtually the full range of verbal commands for aircraft control are available to the operator that are available to an air weapons controller when controlling actual aircraft. These commands were listed in Table 2.

There are two categories of limitations on operator input. The first is that the operator cannot make requests that exceed the aircraft or computer system limitations. These include:

1. The aircraft must be kept within the altitude range of 2,000 to 50,000 feet.

2. The aircraft must be flown between the speeds of .50 and 2.00 Mach.

3. The aircraft should be flown in the airspace within the confines of the gridded ground display, although there is

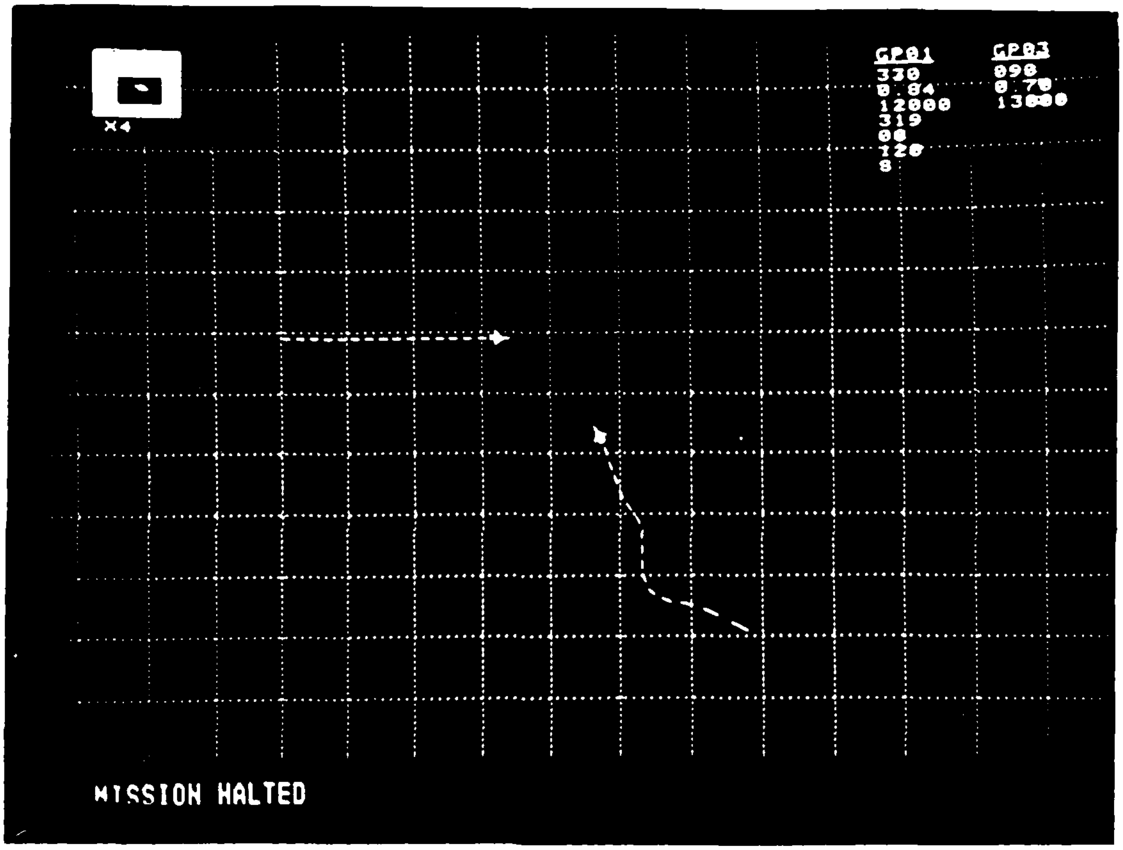


FIGURE 6. GRAPHIC DISPLAY OF AIRCRAFT FLIGHT PATH.

additional room outside this space where the aircraft can be flown before they encounter the limits of the mathematical three dimensional cube. The operator will know when these limits are met because an aircraft will stop its forward motion, although the sideways motion will continue until the aircraft moves into a corner of the airspace. At this point, all motion will stop until the aircraft is turned to a new heading away from the corner.

4. The aircraft cannot be directly transitioned from a climb to a dive, or vice versa. They must first be brought to level flight before an altitude change in the opposite direction can be implemented.

The second category of limitations precludes actions that are illogical, such as:

1. Commanding an aircraft to climb to an altitude lower than its current altitude or to dive to an altitude higher than its current altitude.

2. Commanding an aircraft to turn to a heading outside of the range from 1° to 360°.

3. Giving commands to the third aircraft (GP02) when only two aircraft are displayed.

The limitations which apply to each of the special graphics displays were described in the descriptions of these graphics.

SECTION 4 – FLIGHT PLAN MISSION SCENARIOS

OVERVIEW

The ability to develop and show scripted flight plan mission scenarios is useful both for giving system demonstrations and for observation by students. The primary reason for development of this capability was that most personnel who provided early feedback from the operational and training environments felt that the task of flying the aircraft interactively via the keyboard was too difficult for the majority of students. Thus, the display format was modified so that it could be viewed from a standard television screen, while either using the flight plans in conjunction with live keyboard control or, primarily, through the use of recorded videotapes. Since there are some differences in the software programs and keyboard controls available between the "live flying" version (high resolution CRT) and the flight plan version (TV/videotape), the latter will be described in this section. However, rather than discuss all of the flight plan control and display capabilities, only those that are different between the two versions will be addressed.

The major difference between the interactive version and the flight plan version is that, for the latter, scripted flight plans are built for desired mission scenarios. The flight plans can contain all of the information and verbal commands necessary for aircraft control during the mission. This capability allows a student to observe aircraft intercept tactics and procedures without the necessity of actively controlling the aircraft. Flight plan (mission scenario) development is accomplished through the use of the flight plan compiler.

In order to use the flight plan compiler to develop the scenarios, the flying command language designed for interactive flying is used in modified form. For controlling the aircraft during flight plan playback,

the keyboard function keys are still used, as are the viewing controls, but flying commands are no longer typed on the alphanumeric keyboard; they all originate from the flight plan.

The only major difference in the graphics available in the interactive versus the flight plan version is the addition, in the latter, of the ability to predict and graphically display a portion of the future flight paths of the aircraft. This flight path predictor (look-ahead) display allows students to see graphically where the aircraft will be flying, and their resulting positions, before changes are actually performed. This graphics display will be described in more detail later in this section.

The flight plan version was designed to facilitate the making of videotapes of mission scenarios. Rather than trying to make a videotape of an interactively controlled mission, which would contain operator mistakes, a flight plan can be developed iteratively to show exactly the kind of mission that the instructor wants students to observe. When the flight plan is completed, making the videotape is a simple task involving routing the video cables to a videotape recorder and turning it on in the RECORD mode.

SET-UP

There are two methods to input flight plans: interactively and from storage on a disk. The procedure for each is slightly different.

To compile flight plans interactively:

1. Load the appropriate disk. (High resolution or TV/videotape)

2. Press the computer initialize button on the back of the keyboard.

3. Enter 3 LOAD. (Loads the FORTH nucleus.)

4. Enter 800 LOAD. (Loads the flight plan compiler.)

5. Enter flight plan flying, viewing, and graphic commands interactively.

6. Enter MEND.

7. The flight plan is now compiled and will run to completion.

Although this capability exists, developing and running flight plans interactively is very seldom done because the contents of the flight plan are not stored anywhere for later use. Normally, flight plans will be developed, compiled, and stored on the TV/videotape disk so that they can be modified, refined, and eventually videotaped.

To compile flight plans from a disk:

1. Load the appropriate disk. (High resolution CRT or TV monitor)

2. Press the computer initialize button.

3. Enter 3 LOAD. (Loads the FORTH nucleus.)

4. Edit flight plans blocks using the FORTH editor to develop the desired mission scenario.

5. If more than one block is required to design a flight plan, continue in the next block. The first block must have nnnn LOAD (where nnnn is the subsequent block #) as the last entry in the block. This "links" the blocks together. Repeat as often as required. By convention, flight plans are stored on disk blocks 1300 through 1350.

6. Press the computer initialize button.

7. Enter 3 LOAD. (Loads FORTH nucleus.)

8. Enter 800 LOAD. (Loads the flight plan compiler.)

9. Enter nnnn LOAD (where nnnn is the first block of flight plan data).

10. The flight plan is now compiled and can be run by entering the flight plan number (n PLAN - where n can be any number from 1 through 30).

FLIGHT PLAN COMPILER

The flight plan implementation is, in fact, a true compiler. The flight plans are first entered as "source code" (i.e., a "natural" language) and then are compiled into binary code for execution. Because the details of the flight plan compiler are transparent to the operator, they will not be described here. The only important facts to be aware of are that the compiler must be used when developing flight plans and that a new or modified flight plan must be compiled before it can be run.

FLYING COMMAND LANGUAGE AND SPECIAL INSTRUCTIONS

All of the basic flying commands used in the high resolution CRT version are available in the TV/videotape version. They are used in conjunction with the flight plan compiler, as described earlier, when developing a mission scenario (flight plan). The only major differences between the flying languages in the two versions is that, in the flight plan version, the command words and numbers are reversed and the null words are not used. Table 3 presents a list of the special flight plan

commands that may be used in developing flight plans, but not during interactive control.

KEYBOARD USE

All of the function keys and viewing control keys are available for use with the flight plans. The alphanumeric keyboard, although it is enabled, should not be used because there is a very slow typing response time in this version.

Normally, the only aircraft control and graphics display function keys which would be used, although they are all enabled, are the STOP, GO, GP1, GP2, and TURN TO BEARING function keys. However, changes in viewer position and scene display are always accomplished via the keyboard, including the FRONT VIEW, 45° VIEW, TOP VIEW, and TGT-GP1 CENTER keys, the zoom value numeric key pad, and the directional panning arrows. Use of the flight plan commands corresponding to the remaining available function keys, rather than using the keyboard, will generally produce a smoother-looking videotape, with less possibility for operator error.

SPECIAL TRAINING GRAPHICS

Table 4 provides a list of the graphics available in the flight plan version which relate to intercept geometry training issues.

As can be seen from this table, the training-related graphics displays are quite similar between the high resolution CRT and the TV/videotape versions. There are some additional items available in the TV/videotape version. The only one which requires additional discussion is the LOOK-AHEAD function, with its related commands.

Table 3. Special Flight Plan Terms

TV/Videotape Version

Command	Action	Notes/Limitations
MEND	Similar to END keyboard function key.	Must be last command in last block of each flight plan.
POSITION	Used to establish X, Y, Z position of identified aircraft. Example: GP1 17,200 12,000 4,350	Must be preceded by aircraft identifier. Normally used only at beginning of flight plan. Coordinates are listed in reverse order (Z, Y, X). Altitude used is 1/2 altitude shown on CRT.
IHEAD	Used to establish initial heading of identified aircraft. Example: GP1 270 IHEAD	Must be preceded by aircraft identifier. Normally used only at beginning of flight plan. Heading must be in the range of 1° through 360°.

Table 3. Special Flight Plan Terms (Concluded)

TV/Videotape Version

Command	Action	Notes/Limitations
WAIT	Used to establish number of frames required between commands. Example: GP1 360 RIGHT 25WAIT 90 RIGHT	1 wait = 1 frame. Counting starts at beginning of previous command, not at the end of previous command.
XXXX LOAD	Used to tie flight plan blocks together (i.e., used to load identified block).	Block may be any number, as long as flight plan commands are in identified block. Do not need to reposition aircraft.
NEXT BLK	Loads additional flight plan block (same as XXXX LOAD), and loads next blank source code block. Used to allow additional source code space for long flight plans.	

Table 4. Special Commands and Training Graphics

TV/VideoTape Version

FLIGHT PLAN COMMAND	INTERACTIVE COMMAND	NOTES/LIMITATIONS
JUDY	JUDY	Same as interactive command.
CUTOFF STERN PURSUIT NO ATTACK	CUTOFF STERN PURSUIT NO ATTACK	Same as function key commands.
1/CONE 0/CONE	LEFT CONE RIGHT CONE	Software computes which side interceptor is approaching from and displays RIGHT CONE or LEFT CONE.
NCONE	NO CONE	Same as function key command.

Table 4. Special Commands and Training Graphics (Cont'd.)

TV/VideoTape Version

FLIGHT PLAN COMMAND	INTERACTIVE COMMAND	NOTES/LIMITATIONS
3VECTOR	INTERCEPT VECTOR	Same as function key command. Command both initiates and ends displays.
	Example: 3VECTOR 10WAIT 3VECTOR	
CTRAIL ON CTRAIL OFF	CONTRAIL DISPLAY	Same as function key command. Separate on/off commands.
	Example: CTRAIL ON 10WAIT CTRAIL OFF	
CTRAIL RESET	CONTRAIL	Same as function key command.
BEARON NO BEAR	BEARING VECTOR	Displays graphic vector line, but not alphanumeric current bearing printout on CRT text line. Separate on/off commands.
BEARING	BEARING	Same as function key command.

Table 4. Special Commands and Training Graphics (Cont'd.)

TV/VideoTape Version

FLIGHT PLAN COMMAND	INTERACTIVE COMMAND	NOTES/LIMITATIONS
R+B	BEARING & RANGE	Same as function key command.
$........$	No corresponding interactive command. Used to display open field alphanumeric messages on CRT text line. Example: "GP01 JOIN UP WITH GP03"	Text length must be less than 40 characters.
LOOK-AHEAD	No corresponding interactive command. Used to display future flight path of aircraft. Used with NO-LOOK, OFFLOOK and ONLOOK. See Figure 8 for display.	Tells program to start picking up flight commands for display. May be used up to <u>four</u> times in each flight plan. Cannot have a STOP between LOOK-AHEAD and either NO-LOOK or OFFLOOK.

Table 4. Special Commands and Training Graphics (Cont'd.)

TV/VideoTape Version

FLIGHT PLAN COMMAND	INTERACTIVE COMMAND	NOTES/LIMITATIONS
ONLOOK	Part of look-ahead function. Displays data which have been stored since LOOK-AHEAD.	
NO-LOOK	Part of look-ahead function. Turns off display.	A maximum of 40 frames of command information may be used for display. Stores commands and flight path for reuse.
OFFLOOK	Part of look-ahead function. Turns off display.	Does not store commands and flight path; clears look-ahead memory buffer.

Table 4. Special Commands and Training Graphics (Concluded)

TV/VideoTape Version

FLIGHT PLAN COMMAND	INTERACTIVE COMMAND	NOTES/LIMITATIONS
% ......%	Part of look-ahead display. Displays text on look-ahead flight path, such as turn point identifiers. Position of display is determined by current frame and aircraft location. Allows alphanumeric messages to be displayed as part of graphic. Example: * TP	Text may be up to 8 characters in length.
NO MSG	No similar interactive command. Erases look-ahead messages.	

As Figure 7 shows, this graphic display is a prediction of the future path of both the target and interceptor aircraft, including depiction of the transition point (XP), offset point (OP), turn point (TP), and intercept point (IP), although normally only the OP and TP are displayed.

Beginning at the LOOK-AHEAD command, all flying commands to the aircraft after this point are stored in a memory buffer until either a NO-LOOK, ONLOOK or OFFLOOK are reached. ONLOOK causes the flight paths and the associated graphic points, discussed above, to be displayed and can be placed anywhere in the flight plan after the LOOK-AHEAD. The only difference between NO-LOOK and OFFLOOK is that NO-LOOK does not save the stored data after the data are displayed, whereas OFFLOOK saves the data from this memory buffer and allows the data to be redisplayed when another ONLOOK is reached. All open text messages ($.....$) and all graphics relating to intercept geometry are ignored when LOOK-AHEAD searches through the flight plan to store and display commands.

VIDEOTAPE PRODUCTION

Making videotapes is the same as watching a recorded scenario except that the videotape recorder is plugged in and turned on, and the two Lenco interface devices are on. If they are not, there will not be a picture on the TV.

CAPABILITIES AND LIMITATIONS

There are no error checks in the flight plan compiler except for flying keywords. Inputs to the compiler that are not flying or graphic keywords give the FORTH error prompt "WORD?".

The only limitation is to not use STOP during LOOK-AHEAD.

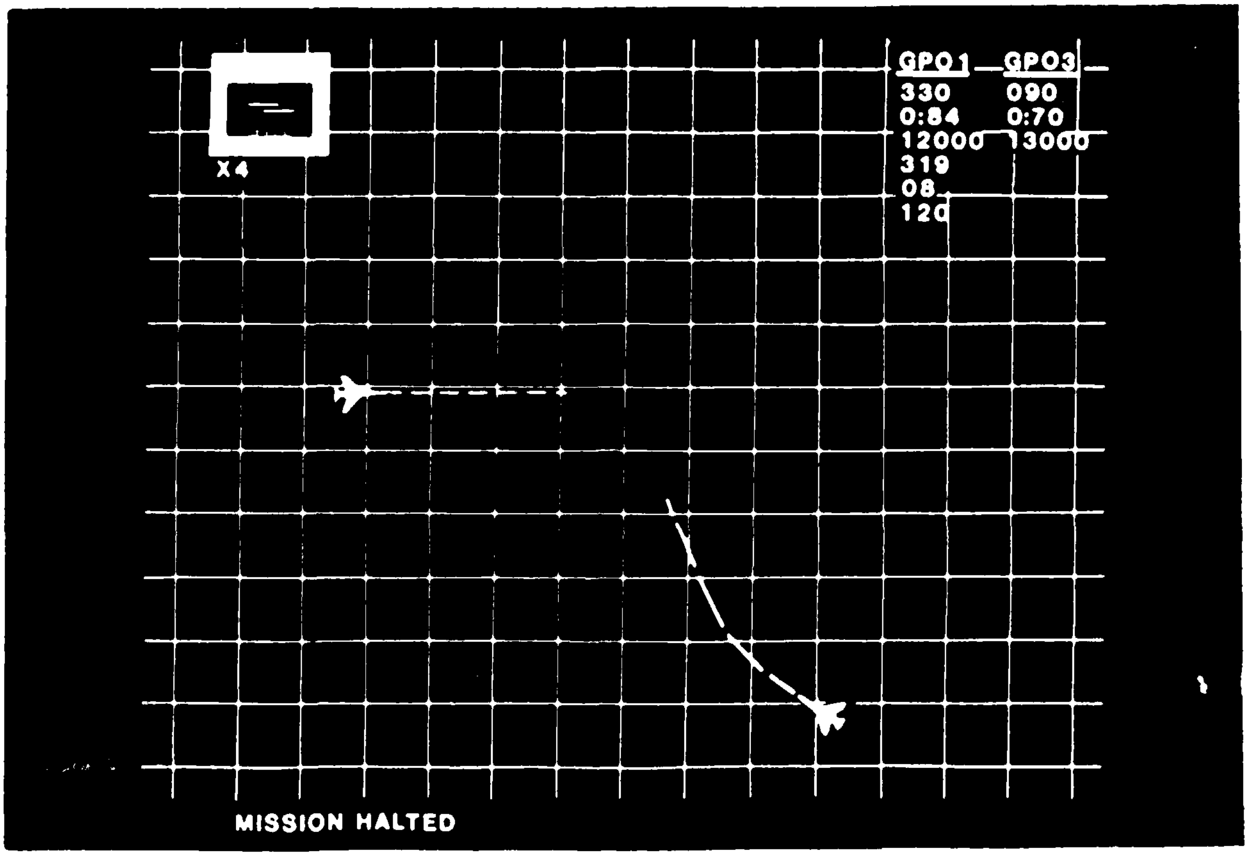


FIGURE 7. GRAPHIC DISPLAY OF AIRCRAFT FLIGHT PREDICTOR (LOOK-AHEAD DISPLAY).

There is room on one disk block for approximately 300 flying and graphic commands. If this is exceeded, a NXT-BLK command is required to "link" the binary blocks together for a continuous flight plan.

SECTION 5 - ERROR MESSAGES AND DEFINITION OF TERMS

ERROR MESSAGES

Error	Reason for Error	Corrective Action
BAD HEADING	Heading less than 1° or greater than 360°, or no heading was entered	Enter correct heading, between 1° and 360°
BAD BANK ANGLE	Bank angle less than 1° or greater than 360°	Enter correct bank angle, between 1° and 360°
NOT TURNING	Tight turn indicated but no turn in effect	Check aircraft designation; implement turn for aircraft
TOO LATE	Tight turn indicated but not enough time to complete	None - info only
IN TURN	Tight turn indicated but tight turn in effect	None - info only
MUST LEVEL OFF FIRST	Trying to change altitude while climbing or diving	Level-off first
ALT TOO HIGH	Trying to climb too high	Enter altitude below 50,000 feet

Error	Reason for Error	Corrective Action
ALT TOO LOW	Trying to dive too low	Enter altitude above 2,000 feet
CANNOT CLIMB LOWER	Trying to climb to a lower altitude	Enter correct altitude
AIRCRAFT IS LEVEL	Trying to level-off when not climbing or diving	None - info only
NO ALT INDICATED	Trying to climb or dive with no altitude specified	Enter correct altitude
CANNOT LEVEL IN TIME	Trying to level-off too soon	None - info only
CANNOT DIVE HIGHER	Trying to dive to a higher altitude	Enter correct altitude
INVALID COMMAND	Trying to enter a command that does not exist	Enter proper command
STILL TURNING	Trying to CONTINUE while aircraft is still turning	Wait until turn is finished
ONLY ONE INTERCEPTOR	Trying to address GP02 when flying only one aircraft (GP01)	Address correct aircraft
BAD PLANE	Trying to address a nonexistent aircraft (not GP01, GP02, GP03 or TGT)	Select proper plane

Error	Reason for Error	Corrective Action
TARGET CANNOT DECLARE ATTACK TYPE	Trying to declare an attack for other than GP01, GP02	Select proper aircraft
NO SPEED INDICATED	Trying to change speed with no new speed given	Enter speed correctly
SPEED TOO SLOW	Trying to enter a speed that is too slow (<.50 Mach)	Enter correct speed (>.50 Mach)
SPEED TOO FAST	Trying to enter a speed that is too fast (>2.0 Mach)	Enter correct speed (<2.0 Mach)
BAD ZOOM	Trying to zoom to a number not between 1-9	Enter correct zoom
IMPROPER ALTITUDE	Altitude wrong on JUDY	Fly into attack envelope
TOO FAR AWAY FROM TARGET	Distance to target is too great on JUDY	Fly into attack envelope
TOO CLOSE TO TARGET	Distance to target is too small on JUDY	Fly into attack envelope
HCA IS TOO GREAT	Heading crossing angle too great on JUDY	Fly into attack envelope

Error	Reason for Error	Corrective Action
BEARING TO TGT IS GREATER THAN 30 DEGREES	Back attack heading on JUDY	Fly into attack envelope
TARGET CANNOT JUDY	Trying to JUDY when GP03 (target) is designated as interceptor	Select proper aircraft (either GP01 or GP02)
NO ATTACK DECLARED	Trying to JUDY without an attack type declared	Enter attack type for selected aircraft

DEFINITIONS OF TERMS

Term	Definition
Compile	The act of translating English-like statements into computer-understandable commands.
Source Language	The English-like statements that are input to a compiler.
Binary (or Object) Code	The computer-understandable output from a compiler.
Listing	A printout of the actions taken by a compiler (i.e., the translation of source statements to binary code.)
Disk Block	The segment (or portion) of a magnetic disk that enters the computer with a READ or LOAD command. Perkin-Elmer disks have 2436 blocks per disk; each block has 1280 characters.

SECTION 6 - QUICK REFERENCE GUIDE

Input	Implementation
Press "Initialize" button on back of keyboard	Initializes computer
3 LOAD	Loads FORTH nucleus into computer main memory.
398 LOAD	Loads flying program software into computer main memory.
800 LOAD	Loads flight plan compiler into computer main memory.
n PLAN	Begins indicated flight plan. "n" must be in range 1 - 30.
END	Completely stops flying program. System must be reinitialized to resume flying.
nnn nnn COPY FLUSH	Copies one block of code into another block. Used to transfer individual blocks.

Input	Implementation
nnn nnn nn COPY BLOCKS	Copies identified number of blocks from one location to another. Used to transfer more than one block at a time.
42 LOAD (Enter Date) MM-DD-YY nnn nnn PRINT SHOW	Prints listing of identified blocks.
42 LOAD (Enter Date) MM-DD-YY LISTALL	Prints listing of all blocks.
BACKUP	Copies blocks 396-1350 from removable disk to fixed disk (2832-3786).
RECOVER	Copies blocks 2832-3786 from fixed disk to removable disk (396-1350).
nnn LIST	Shows identified block on Aydin CRT monitor.
BLOCK nnn BLANK UPDATE	Erases identified block of code.

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